

**TEMPERATURE AND LEVEL DENSITY PARAMETER OF EVAPORATION RESIDUES
PRODUCED IN THE REACTION $^{165}\text{Ho} + 600 \text{ MeV } ^{20}\text{Ne}$**

D. HILSCHER, H. ROSSNER, A. GAMP, U. JAHNKE, A. GIORNI*,
C. MORAND*, A. DAUCHY*, P. STASSI*, B. CHEYNIS**, B. CHAMBON**,
D. DRAIN**, C. PASTOR** and G. PETITT***

*Hahn-Meitner-Institut für Kernforschung, D-1000 Berlin 39,
F.R.G.*

**Institut des Sciences Nucléaires, 53, Avenue des Martyrs,
F-38026 Grenoble, France*

***Institut de Physique Nucléaire, Université Claude Bernard
Lyon I, 43, Boulevard du 11 novembre 1918, F-69622 Villeurbanne
Cedex, France*

****Georgia State University, Atlanta, GA 30303, U.S.A.*

Resumé - Les neutrons de prééquilibre et les neutrons évaporés à partir des résidus d'évaporation dans la réaction $\text{Ne} (600 \text{ MeV}) + \text{Ho}$ ont été utilisés pour déduire l'énergie d'excitation thermique E^* et la température T des résidus. Une valeur du paramètre de densité de niveaux est alors déduite de ces quantités, pour une température de 4.1 MeV.

Abstract - Evaporative and preequilibrium neutrons emitted from evaporation residues in the reaction $\text{Ho} + 600 \text{ MeV neon}$ are exploited to deduce the thermal excitation energy E^* and temperature T of the residues. From these quantities the level density parameter is deduced at a temperature of 4.1 MeV.

I - INTRODUCTION

Since the observation of the disappearance /1/ of binary fusion-fission events in hot nuclei the properties /2/ of hot nuclear matter have obtained a renewed interest. In this contribution we try to determine the level density parameter a at high excitation energy. In order to do this we measure directly the temperature T of an equilibrated fused system and compare this temperature employing the relation $E^* = aT^2 + Bn$ with the thermal excitation energy E^* deduced from other observables. Nuclei can be heated in heavy-ion collisions to high temperatures, however, with increasing bombarding energy an increasing number of preequilibrium (PE) light-particles are emitted prior to the attainment of thermal equilibrium. Thus in order to study the statistical properties of hot nuclei, it is necessary to exploit observables that measure (i) the transfer of linear momentum as a measure of dissipated kinetic energy, (ii) the excitation energy and linear momentum carried away by PE-light-particles, and (iii) the equilibrium temperature of a nuclear system.

II - EXPERIMENTAL METHOD AND RESULT

Neutrons were measured in coincidence with evaporation residues (ER) in the reaction $^{165}\text{Ho} + 600 \text{ MeV } ^{20}\text{Ne}$. The ER were detected with two ΔE - ΔE solid state detector telescopes positioned at $\pm 5.3^\circ$ 27 cm from the target. The ER were separated from other heavy fragments by means of the measured time-of-flight and energy. Neutrons were detected by 9 NE213 scintillators with dimensions 5 cm x 10 cm (thickness x diameter) which were positioned outside of a 2 mm thick scattering chamber 175-125 cm

from the target at angles between 14° and 159° . In front of each n-detector a 2 mm thin NE102 scintillator was positioned in order to detect high energy charged particles. The time resolution of all detectors was mainly given by the beam structure of the SARA-cyclotron at Grenoble and was typically 2.5 ns.

In figure 1 neutron energy spectra are shown in coincidence with ER having velocities between 0.68 and 1.0 cm/ns corresponding to a linear momentum transfer (LMT) of 89 %. Two components can be seen, a low- and a high-energy part corresponding to evaporation and PE-emission of neutrons. These spectra have been fitted with a least square fit method assuming two sources /3/ moving with different velocities to 0° and emitting in each rest frame isotropically. The spectral shape is assumed to be $\sqrt{E} \cdot \exp(-E/T)$. For the low energy component the velocity was set to the measured velocity of ER corrected for energy loss in the $500 \mu\text{m/cm}^2$ Ho-target. For the high energy component the source velocity was used as parameter. Temperature and multiplicity was determined in both cases from the least square fit. The dotted and dashed line in figure 1 are the result of such a fit for the evaporative and PE component, the solid line is the sum of both contributions. For the PE component the neutron energy spectra at all angles between 14° and 159° were used whereas for the evaporative component only the angles between 101° and 159° were used since at these angles the contribution from PE neutrons is sufficiently small so that the deduced temperature of the low energy component is not effected by PE neutrons. The deduced parameters from the fit are shown in figure 2 as a function of ER-velocity for the evaporative component. We associate with the deduced temperature of the low energy component the mean nuclear temperature averaged over the n-cascade after a thermal equilibrium has been reached. The temperature and the associated n-multiplicity is increasing with LMT up to $\langle T_n \rangle = 3.76 \pm 0.13$ MeV and $\langle M_n \rangle = 16.8 \pm 1.0$ neutrons. The temperature T_n of the first neutron can be calculated by $T_n = (12/11) \cdot \langle T_n \rangle = 4.1 \pm 0.14$ MeV.

For the PE component the multiplicity is approximately constant 2.5 to 3.2 neutrons whereas the velocity of the hot moving source is decreasing from 0.66 to 0.49 times the beam velocity whereas the temperature parameter T_{PE} is increasing with increasing LMT. Using the deduced velocity V_{PE} and multiplicity M_{PE} we find that the linear momentum given by $V_{PE} \cdot M_{PE}$ corresponds to 17%, 31% and 65% of the missing LMT to the ER at LMT of 51%, 70%, and 89%, respectively. Since we furthermore find that about half as many PE protons as neutrons are emitted for the highest LMT, the complete missing LMT has been found for the highest LMT in PE nucleon emission. For smaller LMT other not measured processes for instance emission of α -particles or other heavy fragments are contributing. This can also be seen from fig. 3 where the integrated yield for low energetic neutrons between 5.5 and 17.5 MeV is shown for all three LMT. Only for the highest LMT of 89% it is possible to describe the n-yield also at forward angles by using the parameters obtained at backward angles (101° - 159°). For the low LMT at forward angles there is additional n-yield which is not consistent with the assumption of isotropic emission in a rest-frame moving with the velocity of detected ER. In summary, from these findings we conclude that only for the highest LMT of 89%, the measured quantities are complete in order to explain the full missing linear momentum by PE-light-particle-emission. Thus we assume that we can deduced from the measured data also the mean excitation energy $\langle E_{PE} \rangle = 1.5 \cdot M_{PE} \cdot (B + 1.5 \cdot T_{PE})$ carried away by the PE light-particles in addition to the mean linear momentum $M_{PE} \cdot V_{PE}$ taken away by these particles; B is the neutron or proton binding energy plus Coulomb barrier. We can calculate the excitation energy of the ER after attainment of thermal equilibrium:

$$\langle E^* \rangle = m_T \cdot \epsilon_p \cdot \sqrt{1 - \beta_p^2} (\langle V_{ER} \rangle / V_p) + Q_{gg} - \langle E_{rot} \rangle - \langle E_{PE} \rangle; \beta_p^2 = V_p^2 / c^2$$

where m_T , ϵ_p , V_p , Q_{gg} , $\langle E_{rot} \rangle$, and c is the mass of the target, energy per nucleon and velocity of the projectile, ground state Q-value, rotational energy, and speed of light. Employing the relation $E^* - B = aT^2$ we determined the level density parameter a to be (17.2 ± 2.5) MeV for a compound nucleus of mass $A_{CN} = 180$, at a temperature of 4.1 ± 0.14 MeV. The given error includes only the error on T_n .

T_{PE} and M_{PE} , no systematic errors have been taken into account. Thus we find within the given error a similar value for the density parameter at high temperature as the value $a = 17\text{--}20\text{ MeV}^{-1}$ which is given by Dilg et al. /4/.

References

- /1/ Conjeaud, M. et al., Phys. Rev. Lett. 159B (1985) 244.
- /2/ Dean, D.R. and Mosel U., Z. Phys. A322 (1985) 647.
- /3/ Holub, E., et al., Phys. Rev. C33 (1986) 143 and Phys. Rev. C28 (1983) 252.
- /4/ Dilg, W., et al., Nucl. Phys. A217 (1973) 267

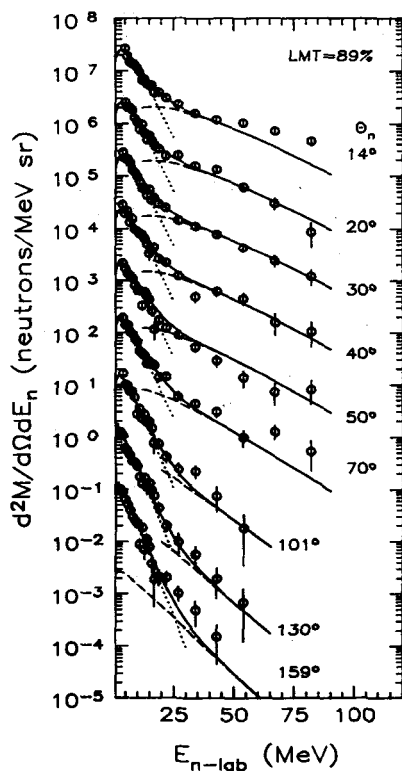


Fig. 1 - Double differential neutron multiplicities in the lab. system.

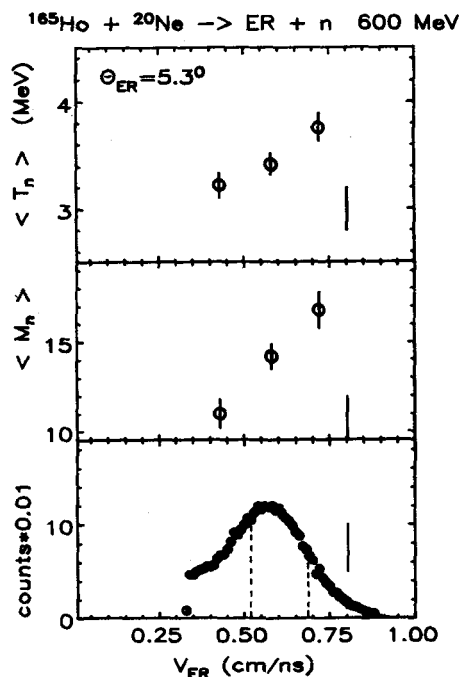


Fig. 2 - Deduced parameters for the evaporative component.

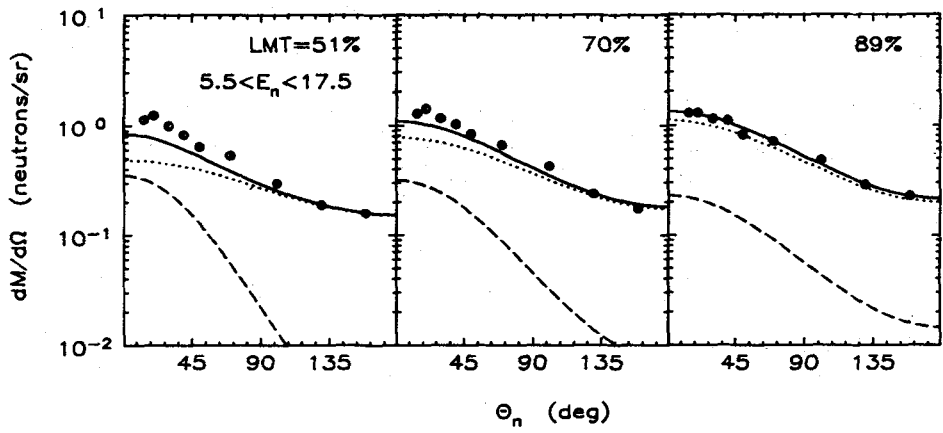


Fig. 3 - Angular correlation of low energetic neutrons. Dotted, dashed, and solid lines correspond to the evaporative-, PE-component, and the sum of both contributions respectively.